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TERRESTRIAL MAGNETISM.—*Terrestrial magnetism in the Twentieth Century.*[1] DANIEL L. HAZARD, Coast and Geodetic Survey.

One of the early presidents of the American Association for the Advancement of Science in his presidential address likened himself to a biennial plant, which for the first year devotes itself to storing up a reserve supply of plant food and in the second year bursts into flower. The character of the flower is an indication of the adequacy of the stored food supply. The president of this society is in much the same category.

The close of the Nineteenth Century witnessed a marked quickening of interest in the study of the earth's magnetism, of which one evidence was the expansion of the magnetic work of the United States Coast and Geodetic Survey, the establishment of a separate division of terrestrial magnetism, and the inauguration of a magnetic survey of the United States.

Now, after the lapse of a quarter of a century, it will not be amiss to take account of stock and see to what extent our knowledge has been increased and how far we have advanced toward the solution of the perplexing problems of the causes of the earth's magnetism and its variations.

It must be borne in mind that the science of terrestrial magnetism is comparatively young. Although Gilbert in 1600 conceived the idea of the earth as a great magnet, similar to a spherical lodestone, he had almost no observational data with which to test his theory, and it was not until 1838 that a fairly correct idea of the nature of the

[1] Address of the retiring president of the Philosophical Society of Washington, presented at the meeting on January 10, 1925. Received January 24, 1925.

earth's magnetism and its distribution was developed by Gauss from his analysis of the results at that time available. With the character of the phenomenon established, the natural philosophers were quick to realize the importance of observations more widely distributed over the earth as a prerequisite for a more effective study.

On the initiative of Humboldt and Gauss, supported by Herschell, Kupffer, and Sabine, there was developed one of the earliest cases of international cooperation for the study of a world-wide phenomenon, which was remarkably successful when the conditions of transportation and communication at that time are considered. Magnetic surveys were undertaken, observers were sent to regions where magnetic observations had not previously been made, including the expedition of Ross to the vicinity of the magnetic south pole, and magnetic observatories were established about 1840, at widely separated points, for the study of the variations of the earth's magnetism. In spite of the imperfect instruments then available, the operation of these observatories served to establish the principal features of the short period variations of the earth's magnetism. Some of them were discontinued at the close of the limited period for which international cooperation had been arranged, but others continued in operation much longer, some (as the one at Toronto, Canada) even to the present day. It is of interest to recall that, thanks to the zeal of A. D. Bache, later Superintendent of the Coast Survey, a magnetic observatory was operated at Girard College, Philadelphia, from 1841 to 1845, and that variation observations were made in this city from 1840 to 1842. One of the observatories established by Russia was at Sitka, Alaska, and was in operation from 1842 to 1867. The results obtained brought out the fact that the variations of the earth's magnetism are different in different magnetic latitudes and called attention to the probability of some relationship between the presence of sun spots and the occurrence of auroras and magnetic storms on the earth. The desire for more information regarding the connection between these two terrestrial phenomena led to further international cooperation in the establishment of a ring of temporary magnetic observatories around the borders of the Arctic Ocean to be operated for three years from 1882.

From that time on the interest in the study of the earth's magnetism steadily increased, not only in the extension of magnetic surveys and in the operation of additional magnetic observatories, but also in the discussion of the results and investigations regarding the cause of the phenomenon.

In most countries the magnetic observatories were established as an

adjunct to existing meteorological observatories and given a subordinate position. At the meeting of the International Meteorological Conference held in Paris in 1896, however, recognition was given to the growing importance of the science of terrestrial magnetism by the appointment of a Permanent Commission for Terrestrial Magnetism and Atmospheric Electricity.

A fresh impulse was given to the growth of interest by the appearance in 1896 of the Journal of Terrestrial Magnetism edited by Bauer, with the cooperation of most of the leading magneticians of the world. This provided a medium for the interchange of ideas and a forum for the discussion of problems of international import of much greater value than the triennial meetings of the international commission and helped to prepare the way for more ready acquiesence in recommendations of the commission requiring international coöperation or agreement.

The investigations of the Nineteenth Century had shown that definite conclusions regarding the causes of the earth's magnetism and its variations could not be reached until more accurate, more detailed, and more widely distributed observations had been made, and the first quarter of the Twentieth Century has been characterized by almost world-wide activity in the accumulation of observational data. More or less detailed magnetic surveys have been made by nearly every civilized country, new magnetic observatories have been established, instruments and methods of observing have been improved, greater homogeneity of results has been secured by national and international comparisons of instruments, and a fuller and more prompt publication of results has been the rule.

In this accumulation of data the United States has played a most important part, and that it has done so is largely the result of the energy and persistence of Dr. Louis A. Bauer. His efforts in 1899, backed by those of Dr. Henry S. Pritchett, at that time Superintendent of the Coast and Geodetic Survey, resulted in the appropriation of funds necessary for the expansion of the magnetic work of that bureau, so that it became possible to make a general magnetic survey of the country, including the islands under its jurisdiction and parts of Alaska, and to establish and operate five widely separated magnetic observatories. This work was planned and the magnetic survey carried well toward completion under his direction.

Designed primarily to meet the practical needs of the navigator and surveyor, this survey at the same time supplied the data needed for the study of the problems of the earth's magnetism.

Realizing that only a small portion of the earth's surface is occupied by the civilized nations and that it would be extremely difficult to secure governmental funds for work to be done outside a country's jurisdiction, Bauer presented to the trustees of the Carnegie Institution of Washington a plan for the establishment of a bureau for international magnetic research, including a world magnetic survey to supplement the work being done by other agencies. This plan was approved, and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was established in April, 1904.

While in charge of the magnetic work of the Coast and Geodetic Survey Bauer had satisfied himself of the feasibility of making magnetic observations at sea with nearly the same accuracy as on land, if a suitable vessel could be obtained. His plan for the world survey, therefore, included provision for a magnetic survey of the ocean areas by means of a non-magnetic vessel. This work at sea was carried on successfully from 1905 to 1921, first on the "Galilee," a chartered sailing vessel, and later on the "Carnegie," a sailing vessel with auxiliary power, built for the purpose so nearly free of magnetic material as to practically eliminate the need of taking account of deviation corrections.

While this work at sea was carried on primarily for scientific purposes, it had great immediate practical value in that it provided the means for correcting the existing world isogonic charts, which were found to be seriously in error because of the insufficient data on which they were based.

At the same time magnetic observers were sent to nearly all accessible regions where magnetic surveys were not being made under other auspices and to some regions usually thought of as inaccessible. Asia, Africa, South America, Central America, Mexico, were all the field of these far-reaching operations. In some instances, as in Canada, one season's work by an observer of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was sufficient to stimulate local interest to a point where means were provided for continuing the work under local auspices. Advantage was taken of these world-wide travels to secure comparisons of instruments with the standards of the various magnetic observatories and other agencies engaged in making magnetic surveys, thus insuring a greater homogeneity of results, in some cases calling attention to defective instruments and in general emphasizing the importance of better instruments and methods.

Some idea of the magnitude of the work done in this world magnetic survey may be gained from the statement that it covered all the ocean areas from latitude 70° north to 60° south, nearly all of the land areas from 30° north to 60° south, excepting India and the Dutch East Indies, and in addition parts of China, Persia, and Canada.

During the same period governmental magnetic surveys have been made in India, New Zealand, Dutch East Indies, South Africa, Canada, and Russia (including Siberia), and resurveys have been made of Japan and the British Islands, and in France, Prussia, and other European countries. Thus it will be seen that during the past 25 years there has been executed a world magnetic survey covering practically the whole surface of the earth between latitude 70° north and 60° south.

At the same time the making of magnetic observations has been recognized as an important part of the work of an exploring expedition, and as a result much information has been obtained regarding conditions in regions which would not ordinarily be reached. This is particularly true of the polar regions. The Ziegler expedition to Teplitz Bay in 1903 and 1904, Amundsen's work in the vicinity of the magnetic north pole, 1903–1906, and along the north coast of Siberia in 1918–1921, and the work of MacMillan's two expeditions served to reduce materially the size of the magnetically unexplored region around the north pole, while the various South Polar expeditions, German, French, British, and Australasian, between 1902 and 1912, supplied a large amount of valuable information regarding magnetic conditions on the borders of the Antarctic continent, and served to locate the position of the south magnetic pole within narrow limits. The operation of temporary magnetic observatories by some of the expeditions made possible a comparison of the magnetic variations in polar regions with those in lower latitudes, the value of the comparison being enhanced by cooperation at a number of leading observatories in the form of a more open time scale on the magnetograms at specified times.

While there were plenty of magnetic observatories in operation 25 years ago, their distribution was very unsatisfactory. Out of about 40 making reports, 70 per cent were in Europe; there was only one in North America (Toronto), none in South America, and only four in the Southern Hemisphere. With the new observatories established since that time there has been a great improvement in the geographical distribution, so that more than 50 per cent of the present active

observatories are outside of Europe and ten are in the Southern Hemisphere. Here again the United States has taken a leading part. Observatories have been operated by the Coast and Geodetic Survey at Cheltenham, Maryland; Tucson, Arizona; Vieques, Porto Rico; Sitka, Alaska, and near Honolulu, Hawaii, and by the Department of Terrestrial Magnetism at Watheroo, Australia, and Huancayo, Peru. Other new observatories at Cordova and New Year Island, Argentina; Vassouras, Brazil; Apia, Samoa; Christ Church, New Zealand; Dehra Dun, India; Helwan, Egypt; Sodankyla, Finland; Meanook, Canada, have all helped to extend the area covered. At the same time some of the older observatories have been discontinued and others have been compelled to move to new sites because of the encroachments of electric car lines and other industrial developments.

Improved methods and instruments have added materially to the accuracy of the results. In the development of new and improved field instruments the Department of Terrestrial Magnetism has been particularly active, to meet the very varied conditions under which it has had to operate, especially in the matter of observations at sea. The design of a portable galvanometer for use with the earth inductor has made it possible to use that instrument in the field in place of the dip circle, and the addition of a special device for rotating the coil of the earth inductor adapted it for use on board ship. The marine collimator permits more accurate declination observations at sea and the sea deflector provides a method of determining directly the horizontal intensity on board ship. Magnetometers have been improved to secure greater ease of handling, adjustment and transportation, and various combination instruments have been devised for use where a very light compact outfit is essential.

The sine galvanometer, of which three types have been developed, provides an electrical method for determining the horizontal intensity, combining rapidity with great accuracy. It is particularly well adapted for a standard instrument, but not well suited for field use.

The variometers designed by Eschenhagen, with very small magnets, have permitted the erection of smaller observatory buildings for the variation instruments and a decrease in the cost of operation, since it is possible to have three variometers record on a single photographic sheet. More complete control of the instrumental constants is also provided.

With so much energy being devoted to the collection of observational data, it would not be surprising to find a falling off in the attention

paid to the discussion of results; but this has been true only to the extent that the utilization of the data has not kept pace with its accumulation. There has been no falling off in the zeal with which magneticians have attacked the problems awaiting solution. Many of those who had taken a prominent part in the investigations of the last half of the Nineteenth Century have gone one by one, leaving their places to be filled by a younger generation. Schott, Eschenhagen, Wild, von Bezold, Snellen, Börgen, Sutherland, Fritsche, Bidlingmaier, Neumayer, Rücker, Birkeland, and Leyst are among those whose names will always be recalled when reviewing the progress during that period.

The fundamental problem of the cause of the earth's magnetism and its variations, attacked from many sides and with various weapons, has thus far withstood the attack. One theory after another has been advanced only to be withdrawn before the irresistable assault of observed facts. Some theories fitted well enough qualitatively, but were entirely inadequate when quantity was taken into account, while others which seemed plausible at one stage of our knowledge had to be discarded when our knowledge increased.

Advances in other fields of science have been seized upon in the hope that they might furnish a clue to the mystery of the earth's magnetism. Cathode rays, the electronic theory of matter, the constitution of the sun, and the probable condition of the interior of the earth are all being studied as to their possible bearing on the magnetic field of the earth.

Gilbert's conception of the earth as a great magnet uniformly magnetized about its axis of rotation, and subsequent modifications, had to be discarded with the acceptance of a very high temperature for the interior of the earth and the recognition of the demagnetizing effect of heat, coupled with the small amount of magnetic material found in the visible rocks. At the same time the magnitude of the anomalies (the departures from a uniform magnetization) indicated the presence of large masses of magnetic material not far from the surface. Recent investigations in various fields have suggested the possibility that some of the properties of matter subjected to very great pressure may be materially different from those observed in the laboratory at ordinary pressures. Susceptibility to magnetization may be one of those properties, and the Department of Terrestrial Magnetism, with the cooperation of the Geophysical Laboratory of the Carnegie Institution of Washington, is arranging a series of experiments designed to test the matter.

Nippoldt, in 1921, returned to the idea of the earth as a magnetized sphere, because of the difficulty of providing a satisfactory system of electric currents to account for the observed magnetic field. He advanced the theory that the principal part of the earth's magnetic field consists of a non-homogeneous magnetization of the earth's crust down to a depth of about 20 kilometers. In addition, there may exist for the earth's nucleus a magnetic field symmetrical both about the axis of rotation and about the equatorial plane which may have arisen in the same manner as the general magnetic field of the sun. He assumed that the proportion of magnetite in the earth's crust increases with depth below the surface, but that the distribution is not homogeneous. He also assumed an inner core composed of iron, nickel, and cobalt, as suggested by geophysicists, with the possibility that it may be susceptible of magnetization in spite of the high temperature, in view of the magnetic effects observed on the sun by Hale.

Adolph Schmidt points out that even on the assumption that at a depth of 20 kilometers the earth's crust is composed entirely of magnetite, the *average* susceptibility would not be great enough to account for the observed conditions at the surface.

When it became apparent that the conception of the earth as a permanent magnet could not be sustained, the idea was advanced that the earth's magnetic field might be due to electric currents flowing about the earth, either below the surface or in the atmosphere—the earth an electro-magnet. The mathematical analysis of the earth's field according to the method devised by Gauss and extended by Neumayer and Petersen (1891), and Schmidt (1896), indicated that a small portion of the earth's magnetism, perhaps one-fortieth, could be referred to forces outside the earth, another small portion to vertical electric currents, but by far the larger part to a system of forces within the earth. A new analysis made by Bauer in 1922, using improved data based on modern observations, gave approximately the same result. He reached the conclusion that for a satisfactory representation of the observed data it is necessary to recognize the existence of an internal magnetic system constituting about 94 per cent of the total field, and an external system and a non-potential system about equal to each other in amount.

A comparison of his results with those previously obtained for the epochs 1842 and 1885 indicated that the intensity of magnetization of the earth had been decreasing during the 80 year period at an average annual rate of 1 part in 1500, a rate of loss which it is hard to reconcile

with the age of the earth and the present intensity of magnetization unless we suppose that there have also been periods of increasing intensity.

Bauer also carried out the harmonic analysis separately for parallels of latitude at 5° intervals from 60° south to 60° north and found an apparent correlation between distribution of land and water and intensity of magnetization, the intensity being greater for the parallels falling largely on the land.

In an earlier (1911) discussion of the earth as an electro-magnet, Bauer took the position that the system of magnetic forces within the earth required by the Gaussian analysis might be the result of magnetizing currents outside the earth, namely, negative electric currents circulating from west to east, but he later withdrew this hypothesis, after further study of the problem. As it seems to be established that the diurnal variations of the earth's field and the disturbances must be ascribed to outside currents, it would be much simpler to account for those changes if the field itself is due principally to outside currents.

The idea of the earth as an electro-magnet naturally suggests the possibility that its magnetism may be caused by its rotation. This possibility has been the subject of much study, particularly by Barnett, who has shown experimentally that a piece of iron may be magnetized by rotation; but the observed effect was much too small to account for the earth's magnetism. Swann attacked the problem mathematically and concluded that any effect due to rotation would be too small to be detected. In 1900 Sutherland suggested as a possible cause of the earth's magnetism the rotation of an electrostatic field within the earth (a positively charged core and a negatively charged crust, or vice versa), as Rowland's experiments had proved that a moving charge of electricity produces a magnetic field analagous to that of a current, but this theory proved untenable when submitted to analysis.

The development of the electronic theory of matter with the atoms consisting of a positively charged nucleus surrounded by negatively charged electrons led Sutherland to suggest that if for some unknown reason connected with gravitation the negative charge of the atom was further from the center of the earth than the positive charge by only 0.4×10^{-8} cm., it would account for a magnetic field comparable with that of the earth. Here again, when the theory was submitted to analysis and the electronic theory was more fully developed, it was seen that Sutherland's hypothesis was untenable either qualitatively or quantitatively.

Failing to find a satisfactory explanation of the earth's magnetism on the basis of the known properties of matter and the accepted laws of electro-dynamics, J. J. Thomson, Sutherland, Bauer, and Swann have suggested that we may have to look for some slight but fundamental modification of those accepted laws, possibly as regards the mutual attraction and repulsion of moving positive and negative electrons, similar to a suggestion by H. A. Lorenz regarding the cause of gravitation. Indeed there seems to be growing a belief that gravitation and terrestrial magnetism are very closely allied and probably to be traced to a common origin.

Realizing the difficulties in the way of a direct attack on the problem, especially before more complete observational data was available, many magneticians have turned their attention to a study of the variations of the earth's magnetism and their correlation with associated phenomena, such as atmospheric electricity, earth currents, auroras, sun spots, solar radiation, meteorolcgical phenomena, hoping in this way to throw light on the main problem. In particular, magnetic storms, those irregular disturbances of large amplitude and comparatively short duration, have been the subject of much study.

From the time of the earliest comparisons of photographic records from widely separated observatories, it was recognized that the more severe magnetic disturbances occur at practically the same time all over the earth, and further comparative study of abrupt beginnings and sharp turning-points indicated strict simultaneity, the departures therefrom being ascribed to errors inherent in the time measurements, so that more accurate determination of the time of occurrence of such salient features was suggested as a method of determining differences of longitude. In fact, van Bemmelen, from the mean of 53 abrupt beginnings, computed the difference of longitude between Batavia, Java, and Greenwich, and obtained a value differing by only 9 seconds from the one derived in the usual way.

On May 8, 1902, there occurred a magnetic storm, the abrupt beginning of which coincided with the eruption of Mont Pelée, as nearly as the time of that disastrous outbreak could be determined. This apparent coincidence suggested the possibility that the two phenomena might be related. Bauer made a study of this storm in 1910, based on the records of 25 observatories, and reached the conclusion that it did not begin at the same instant all over the earth, but on the contrary had its origin in about longitude 75° west of Greenwich and traveled eastwardly around the earth, requiring between three and four minutes

to complete the circuit. A similar study of another storm of distinctive features supported this conclusion.

For further evidence on this very important question, Faris made a study of 15 abruptly beginning storms occurring in 1906–1909, using the records of the five magnetic observatories of the Coast and Geodetic Survey, and his results apparently confirmed Bauer's conclusions, the transmission time again coming out about 3½ minutes. It was necessary, however, to assume that some of the storms traveled from west to east, as had been suggested by Bauer. Faris pointed out that probably the greater part of the error of determining the time of an abrupt beginning is due to the difficulty of selecting the exact point of beginning on the curve. Bauer accordingly secured reports from 23 observatories on the same storms which Faris had investigated, making an effort to secure more homogeneous data by means of tracings of portions of the curves showing the points selected for measurement. A discussion of these more accurate data failed to confirm the conclusions drawn from the earlier investigations. Rodés also made a study of a number of abrupt-beginning storms between 1910 and 1921 and found no evidence of storm propagation of the character suggested by Bauer, but he did find some indications that a terrestrial magnetic storm may begin at the "front meridian," that portion of the earth, that is, which would be the first to meet a stream of electrified particles coming from the sun, occurring later on both sides of that meridian.

The close correlation between the occurrence of magnetic storms and auroras and the presence of large spots on the sun naturally led to attempts to trace a causal relationship. It was soon seen that a direct magnetic effect by the sun was out of the question. With the development of the idea of currents of electricity being the cause of the earth's magnetism, different forms of electric discharge emanating from the sun were successively put forth as the cause of the observed terrestrial phenomena, the theories advanced keeping pace with the development of our knowledge of electrical discharges in a vacuum.

Birkeland, Arrhenius, and Nordmann agreed in considering the auroral rays as a luminescence produced by the absorption of cathode rays in the upper atmosphere, and attracted toward the earth's magnetic poles. Birkeland, who devoted many years to the study of auroras, first supposed that the cathode rays were emitted directly from the sun, but later he advanced the modified theory that cathode rays from the sun set up electric currents in the atmosphere which in turn emit secondary cathode rays. He supported his theory by the production of artificial auroras in the laboratory, about a magnetized steel ball in a tube of rarefied air exposed to cathode rays.

Paulsen in 1906, after calling attention to the difficulties with earlier theories, sought to explain the aurora and magnetic storms by a strong ionization of the upper layers of the atmosphere above the zone of maximum frequency of the aurora.

Störmer, who had worked with Birkeland in both his observational and experimental studies of the aurora, knowing that the phenomenon of the concentration of cathode rays toward a single magnetic pole had been mathematically treated by Poincaré, thought it might be worth while to determine mathematically the trajectories of electric corpuscles coming from the sun into the magnetic field of the earth, hoping to bring out the principal features of the aurora. These studies began in 1903 and covered a period of about ten years. Störmer simplified the problem at the outset by treating the earth as a spherical magnet and neglecting the relative motion of the earth and sun and then modified the results obtained for this simple case to correspond to the more complex conditions actually existing. In this way he was able to develop paths for the corpuscles which seemed to fit the general features of the aurora as it appears in nature and of the artificial aurora of Birkeland, and thus tended to strengthen the corpuscular theory of its origin.

The correlation of magnetic storms with sun spots, although very satisfactory when based on yearly averages, leaves much to be desired when individual cases are considered. Thus severe magnetic storms sometimes occur when no large sun spots are visible and, on the other hand, the appearance of a sun spot is not always accompanied by a magnetic storm. To account for this, Maunder advanced the theory that the solar activity which gives rise to magnetic disturbances on the earth does not act equally in all directions but along narrow well-defined streams, not necessarily truly radial; that these streams arise from active areas of limited extent; that these active areas are not only the source of our magnetic disturbances but are also the seats of the formation of sun spots; that these areas can be active both before a spot has formed and after it has disappeared. The fact that large magnetic storms frequently follow each other at an interval approximating the time of revolution of the sun and that such recurrence has been traced for several rotation periods, not every recurrence being accompanied by a visible sun spot, requires some such explanation as that suggested by Maunder.

Chapman, after a detailed analysis of a number of magnetic storms, attempted to show how some of their characteristics may be produced

by streams of electric particles entering the atmosphere from the sun, but this theory, like so many others, failed to fit all the facts.

The researches of Hale at the Mt. Wilson Solar Observatory on the evidence of magnetic polarity in the sun spots occurring in pairs and on the general magnetic field of the sun have further stimulated the efforts to trace a connection between solar and terrestrial magnetism and opened the way for a study of the details of the sun's magnetic field. According to the most recent analysis by Seares, the sun's magnetic axis makes an angle of about 6° with the axis of rotation.

When we consider the diurnal variation of the earth's magnetism a different problem is presented. Here we have to deal with a phenomenon which is a function of local mean time, as contrasted with magnetic storms, which, as we have seen, occur everywhere at practically the same absolute time. Attempts have been made to correlate the diurnal variation with changes of pressure, temperature, humidity, and other terrestrial phenomena which have a period the same as the earth's rotation, but without success. Broadly speaking the diurnal variation is a function of the position of the sun above the horizon, distinctly a local phenomenon. The extremes and the principal portion of the variation occur during the daytime. During the night hours there is comparatively little variation. In view of this fact, it occurred to Bauer that the interposition of the moon between the earth and the sun at the time of a solar eclipse might have an appreciable effect on the earth's magnetism. Accordingly he arranged for special observations by observers of the Coast and Geodetic Survey at the time of the total eclipse of May 28, 1900, at stations extending from Alabama to Maryland. The results indicated a small but definite disturbance associated with the passage of the moon's shadow across the place of observation and of the character to be expected. Similar observations have been made at all accessible solar eclipses since that time, principally on the initiative of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, but with the cooperation of other observers in the countries crossed by or contiguous to the belt of totality. These have in general confirmed the results of the first series, though the effect produced by an eclipse is so small that it cannot be definitely recognized when ordinary magnetic disturbances are in progress.

Much study has been given by Chree, Chapman, and others to the details of the diurnal variation, particularly to a comparison between conditions on quiet days and disturbed days and between conditions

in high and low magnetic latitudes. Material has been provided for a more accurate study of those features which are not purely local, such as the effect of change of geographic position on the form and amplitude of the curves, through the publication by many observatories of diurnal variation tables based on five internationally selected quiet days, thus eliminating to a large extent the lack of homogeneity which magnetic disturbances might introduce.

Still another problem is presented by the secular change of the earth's magnetism, which requires centuries for its development. Time enough has not yet elapsed since the beginning of measurements of the earth's magnetism to fully determine the characteristics of this change, but we do know that it does not go on indefinitely in one direction; eventually there is a reversal.

In the case of declination the records at some European stations go back far enough to show two reversals, with a range, in the case of London, of 35° in a little over 200 years. This suggested the idea of periodicity and a motion of the magnetic pole as the cause of the secular change, as it seemed possible to follow the occurrence of a particular phase from east to west around the earth.

Data accumulated during the past 25 years show that the phenomenon is very complex. The change is by no means regular; the periods indicated for different stations differ widely; unexpected reversals occur and there are undoubtedly waves of shorter period superimposed upon the primary wave, if indeed there is a primary wave. It is impossible to predict with accuracy what conditions will be ten years from now.

Bauer has made a mathematical analysis of the secular change of the earth's field as a whole, and has concluded that the system of forces involved is partly within the earth and partly outside and that the strength of the field is changing as well as its direction. It is not easy to conceive of a system of forces acting for a long term of years to produce such a great change in the direction of the earth's magnetic field. A loss of magnetism would not be surprising from our experience with artificial magnets, but such a rapid loss as one part in 1500 per year for 80 years or more requires verification on the basis of more accurate secular change data for the whole earth.

Variation of solar activity has been suggested as one cause of the secular change of the earth's magnetism. The periodic change in the number of sun spots, which is undoubtedly a symptom of varying solar activity, is paralleled by an eleven-year period in the secular change,

and Bauer has attempted to trace a relationship between changes in the earth's magnetism and the changes of solar activity indicated by Abbott's observations of the amount of heat given off by the sun. Abbott's observations have not yet been going on long enough, however, to draw any definite conclusions.

Any theory of the earth's magnetism based on electric currents either within or outside the earth must take account of the currents actually observed, and one of the features of the progress of the past twenty-five years has been the awakening of interest in the study of atmospheric electricity and earth currents and the development of instruments for measuring them which can be relied upon to give results of the required accuracy.

Before long we may also expect the increase in our knowledge of radio transmission to throw light on electrical conditions of the atmosphere at higher levels.

From this summary of the accomplishments in the field of terrestrial magnetism during the first quarter of the Twentieth Century, it will be seen that there has been no sudden increase in knowledge, no epoch-making discovery, but just a steady advance. The old problems still confront us, but in a modified form. Their scope has broadened tremendously and any theory to explain the earth's magnetism must take into account the structure of the atom as well as the structure of the universe. At the same time new weapons and new methods of attack have become available and the workers in other fields of science—astronomers, physicists, geologists, chemists—are now the allies of the magneticians. Moreover, an accurate magnetic survey of practically all of the accessible land and water areas and the operation of additional magnetic observatories, better distributed, have provided us with reliable knowledge of the distribution of the earth's magnetism—the facts which must form the ultimate test of any theory.

Finally there has been an increasing recognition of the importance of international cooperation, so well expressed by Rücker in 1898, when he said: "For those who would unravel the causes of the mysterious movements of the compass needle, concerted action is essential. They cannot indeed dispense with individual initiative or with the leadership of genius, but I think all would agree that there is urgent need for more perfect organization, for an authority which can decide not only what to do, but what to leave undone." We may confidently expect that the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union will eventually develop into an organization of the character suggested by Rücker.

GEOLOGY.—*A revision of the Pleistocene Period in North America, based especially on glacial geology and vertebrate paleontology.* OLIVER P. HAY, Carnegie Institution of Washington.

1. EXPLANATORY

For some years the writer has been studying the fossil vertebrated animals of the North American Pleistocene period in the endeavor to determine the genera and species which then existed, the geological stages during which the various species lived, their origin, their distribution, and the causes of the disappearance of as many as did disappear. Naturally, it has been necessary to study the geology of the Pleistocene, in order to correlate the history of the animals with the geology.

For the writer the Pleistocene is synonymous with the Glacial period. As regards the beginning of this period, we may not know when the first accumulations of ice began at the centers of radiation in Canada; but we may credit to the Glacial period such phenomena in southern British America and in the United States as (1) glacial drift produced from a continuous sheet of ice; (2) moraines from local glaciers provoked by a general lowering of the climate; (3) the disturbance of the previous drainage. The close of the Pleistocene was marked by the retreat of the last ice sheet to its center in Labrador.

I accept the results of the glacialists who seem to have established the occurrence of five glacial and four interglacial stages. During these stages there appear to have been produced such important effects, geological and biological, that they mark off as many distinct divisions of the Pleistocene period; but not all of them have the same value.

2. THE VICISSITUDES OF THE PLEISTOCENE VERTEBRATES

In considering the vertebrate palaeontology of North America during the Pleistocene, the following facts need attention. Had it not been for certain geological changes which occurred just before or at the beginning of the Pleistocene, our continent would have been occupied by animals very different from those found here when Columbus made his discovery. The occupants would have been purely the descendants of the late Tertiary animals. There would have been found strange carnivores, probably various saber-tooth tigers; one-toed, probably also three-toed horses; tapirs; various species of camels

and peccaries; short-jawed and long-jawed mastodons; possibly rhinoceroses. However, movements of the earth's crust opened the gates of Asia and of South America and permitted hosts of vertebrates to enter from those lands. From South America there arrived six or more genera of giant ground-sloths, large and small armadillos, glyptodons, and huge capybaras. A few of these had filtered in during the upper Pliocene, but most of them apparently during the wane of the first glacial stage or early in the first interglacial.

From Asia there came, in at about the same time, elephants of several species, the American mastodon, probably most of the Pleistocene and Recent dogs and cats, the bears, and the bisons, musk-oxen, sheep, and reindeer; also moose of two or three genera. Hence, shortly after the beginning of the Pleistocene, at least early in the first interglacial stage, there was an abundant and varied fauna, the product of three continents. There were copious materials from which new forms might be evolved, and the environment seemed favorable. What was the result? When white men reached this country the fauna had become impoverished. Orders, families, and genera, especially of large mammals, which were present at an early stage of the Pleistocene, had disappeared. All the great edentates, the ground-sloths, the glyptodons, and the great armadillo *Nothrotherium*, also the capybaras, sent north from South America, had perished. The saber-tooth tigers had become extinct; the whole order of elephants and mastodons had been swept away. Of more than a dozen species of horses which had existed, none was left. Of six or more kinds of bisons, only one remained.

Had other forms been evolved to take the places of those species which had been exterminated? Assuredly, during that time no new family had been evolved. Probably not even a new genus had come into existence. It may be that certain forms had developed some of the small differences that mark species. It was, however, a time of extinction of species, and a time of little evolution. How can we account for this zoological catastrophe? The interglacial stages were certainly favorable for plant and animal life. Apparently it was the glacial stages which brought about the extinction of so many imposing animal forms. The reasons are clear. The area for occupation was greatly diminished by the ice sheets. Much of the remaining area was made inhospitable to most animals and to their habitual food-plants. Snow storms and cold rains must have prevailed far southward and been conducive to the extinction of the less hardy species.

3. THE STAGES OF THE PLEISTOCENE

The stages of the Pleistocene are shown below. We know little from actual discovery about the vertebrate life of the first glacial stage, the Nebraskan; but it must have been made up of some species from South America, some from Asia, but principally of native species remaining over from the Pliocene. Many of the latter must have succumbed to the inclemencies of the climate. When the warm interglacial Aftonian came on, there were present, from persistence or from recent immigration, saber-tooth tigers, elephants (among them *Elephas imperator*), mastodons of several species, a dozen or more species of horses, several species of bisons, tapirs, camels, numerous ground-sloths, forming thus a rich fauna. Next came the Kansas glacial stage. After that stage we find few saber-tooths, no *Elephas imperator*, few species of horses, no camels, few species of ground-sloths, no glyptodons, no capybaras. The first glacial stage had thus almost annihilated the descendants of the Pliocene mammals, not inured to a severe climate. The second glacial stage had nearly wiped out the South American contingent. The survivors were mostly of northern Asiatic origin, hardened to an inclement environment. *Elephas imperator* had probably reached North America from southern Asia and was a weakling. The faunal change that occurred during the first three stages appears to have been more profound than that of the rest of the Pleistocene. Hence I believe that the division of the Pleistocene into Earlier and Later expresses best the history of the North American vertebrate animals during the Pleistocene.

Pleistocene	Later	Wisconsin glacial. *Peorian interglacial.* Iowan glacial. *Sangamon interglacial.* Illinoian glacial. *Yarmouth interglacial.*	Few edentates, few or no horses, no camels, no *Elephas imperator*, one or two mastodons, fewer large cats.
	Earlier	Kansan glacial. *Aftonian interglacial.* Nebraskan glacial.	Many edentates, many horses, many camels, *Elephas imperator*, several mastodons, many large cats.

4. PLEISTOCENE GEOLOGY. THE EASTERN AND SOUTHERN COASTAL TERRACES

As regards the geology of the Pleistocene, the writer believes that about the beginning of the period there were extensive elevations of

large parts of the continent, perhaps of the whole of it. These elevations affected certainly the coastal regions and the regions of the Great Lakes. An important effect of these uplifts was the production of deep and wide excavations of the valleys of many of our large rivers. I accept the conclusions of our geologists that during the time of the last glaciation, the Wisconsin, the areas occupied by the ice were depressed, not greatly at and somewhat beyond the border, but increasingly so farther northward. The subsidence is attested by beds of marine shells along the coast at heights varying from 33 feet at Nantucket Island to 200 feet or more on the coast of Maine; on the coast of Labrador, 500 feet. Shell beds are found along the St. Lawrence River at heights of 250 feet; along Ottawa River, 450 feet. As to the Atlantic and Gulf coasts, from New Jersey to Mexico, it is a widely accepted theory that they have been sunken beneath the sea, once during the late Pliocene, three times during the Pleistocene, resulting in the production of 4 or more sets of marine terraces. The utter lack of marine fossils in these terraces, except for a few feet in the lowest one, seems sufficient to show the untenability of this theory. Other causes must be sought to explain the terraces. This is the work of the geologists; but they must not overlook the paleontology of these terraces.

Furthermore, it has been the custom to distribute the last three terraces with impartiality to widely separated times of the Pleistocene. The lowest one, having an elevation of perhaps from 40 to 100 feet above the sea, has been regarded as belonging to the late Pleistocene, about the time of the Wisconsin glacial stage. On the contrary, deposits on this lowest terrace, from New Jersey to the west coast of Florida, especially from North Carolina, contain an abundance of vertebrate fossils of the first interglacial stage, the Aftonian. That is, they contain the Aftonian elephant, *E. imperator*, species of mastodon found in only early Pleistocene deposits, many species of horses, camels, saber-tooth tigers, and various great edentates not found in later Pleistocene deposits. The low plain along the Gulf coast of Texas belongs to about the first interglacial, inasmuch as, down to sea-level, it contains remains of giant sloths, early Pleistocene elephants and mastodons, and camels. All those terraces then, low and high, must have been formed during the late Pliocene and the Nebraskan times. Since that time, no part of our coast south of New Jersey has been submerged by the sea, beyond a very few feet.

In Florida and farther north, beneath the deposits regarded by the

writer as belonging to the Aftonian interglacial stage, is a widely extended and deep accumulation of Pleistocene marine mollusks. I believe that this shell bed belongs to the Nebraskan stage. In Publication 322 of the Carnegie Institution of Washington, on pages 9–10, I provisionally referred to the Nebraskan, the Bone Valley phosphates and the Alachua clays. As to the Bone Valley deposits, it appears that an error was committed. Regarding the Alachua clays, it is possible that further exploration will show that distinct Pliocene and Miocene deposits are also present; but, so far as the writer knows, this has not been done.

The terraces of all the great rivers of Texas, the lower, as well as the upper ones, contain the vertebrate fossils which characterize the first interglacial stage. There is hardly any other explanation than that those great valleys were excavated during the late Pliocene and the early Pleistocene. Possibly they were excavated during the Nebraskan, refilled during the Aftonian, the fossils being then included, and the deposits removed partially at a later time.

5. THE AGE OF THE LAKE BONNEVILLE DEPOSITS

In his work on Lake Bonneville, G. K. Gilbert recognized two stages of high water. During the first high stage the yellow clays of the Lower Bonneville were laid down; during the second, the Upper Bonneville White Marls. Gilbert referred these marls to the last of his two recognized glacial stages, and this must be regarded as the Wisconsin. In these beds no vertebrates which might decide the geological age of the deposits were found; but Gilbert referred the remains found in Lake Lahontán to deposits believed to correspond in age to the Upper Bonneville. These remains belonged to a proboscidean, a bison, a horse, and a camel. At Astor Pass, in deposits regarded as equivalent to the Upper Bonneville, two species of horses, a camel, and a large tiger-like cat have been discovered, all identical with or closely related to, animals found at La Brea, California, of early Pleistocene age. These discoveries seem to push back the Upper Bonneville beds to about the time of the Aftonian, or early Kansan stage, unless Gilbert erred when he correlated the Bonneville beds with the Lahontan.

During the past summer, collections were made by Messrs. W. F. Foshag and S. H. Cathcart, of H. G. Ferguson's party, on the Walker Lake beach and along Walker River. In these, remains of bison, a

large and a small horse, and a large species of camel were found. The camel is closely related to a large species found in Colorado, Idaho, Oregon, and perhaps Washington.

6. THE PLEISTOCENE OF THE PACIFIC COAST

The Pleistocene geology and vertebrate paleontology of the Pacific coast are of the highest interest. The early Pleistocene is well represented there; but many contrasts present themselves when the deposits are compared with those of the Atlantic coast. At no place along the coast of California did glaciers enter the sea. The coast was not at rest for long, but with oscillations, it was raised and depressed and raised again. When near sea-level the rocks were carved into terraces and these are now found at various heights up to 1,000 feet or more. Their origin is not doubtful, for marine fossils abound in them. At San Pedro, as we learn from Arnold's monograph[1] there are Upper Pliocene deposits filled with marine shells. These deposits are overlain by the Lower San Pedro Pleistocene from which about 250 species of marine organisms, mostly mollusks, have been collected. These indicate a cold climate. T. S. Oldroyd has recently studied[2] the Lower San Pedro mollusks, and he confirms Arnold's view regarding the climate. Above this deposit comes the Upper San Pedro, from which 250 species of marine mollusks have been secured. These fossils indicate a warmer climate than that of today. Arnold stated that the fauna resembled more nearly that now living two or three hundred miles further south. He believed also that this formation does not mark the close of the Pleistocene. He says: "All of this evidence, then, leads to the conclusion that there has been a sufficient lapse of time since the deposition of the Upper San Pedro strata to admit of marked faunal and orographic changes."

Now at San Pedro, in the Upper San Pedro beds, have been found remains of a bison, a horse, a *Nothrotherium*, a camel, and *Elephas imperator*, the last three animals being characteristic of early Pleistocene times. The evidence shows, therefore, that the Lower San Pedro belongs to the first, or Nebraskan, glacial stage and the Upper San Pedro to the Aftonian interglacial.

These same Upper San Pedro beds are found at many points along the coast of California. At Port Los Angeles, about 25 miles from San

[1] ARNOLD, R.: *The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California*, Calif. Acad. Sci. Mem. 3. 1903.

[2] OLDROYD, T. S.: Proc. U. S. Nat. Mus. 65: art. 22. 1925.

Pedro, and about as many miles nearly directly west of Los Angeles, Arnold obtained 16 species of marine mollusks which he referred to the Lower San Pedro. The overlying beds did not bear fossils, but Arnold regarded them as probably Upper San Pedro. Farther east, 7 miles west of Los Angeles, is the La Brea locality, famous for its vertebrate fossils preserved in the asphalt pits. Here the Pleistocene, as described by Arnold,[3] is from 50 to 100 feet thick and consists of clay, sand, and gravel which have been brought down from the mountains. This material is impregnated with oil and asphalt. In the La Brea locality one must rely, not on marine fossils, but on land animals. The specimens collected by Merriam and his associates, and amounting to thousands, are usually in a fine state of preservation. The list of species, birds and mammals, is a large one. In general it may be said that the genera and the species of mammals are those which characterize the first interglacial stage elsewhere; and they may be referred without hesitation to the Aftonian.

7. THE PLEISTOCENE OF THE DESERT REGIONS OF OREGON AND WASHINGTON

At Christmas Lake, Oregon, 20 or more species of fossil mammals, more than 50 species of birds, and a few fishes have been collected. The mammals include four species of camels, the imperial elephant, and a horse; all of which the writer regards as indicative of the first interglacial stage.

At what is now a small settlement called Delight, about 12 miles northwest from Washtucna Lake, have been collected mammals including probably 2 species of horses, 3 camels, and a large ground-sloth (Mylodon). The writer regards the collection as belonging to the Aftonian interglacial stage.

8. THE LATER PLEISTOCENE AND ITS VERTEBRATE FOSSILS

In deposits laid down on the Wisconsin drift, especially in lakes, ponds, and swamps, are found 1 species of ground-sloth, 2 or more species of peccaries, 3 or 4 species of elephants, perhaps 2 mastodons, a moose, and a giant beaver, all now extinct. There have been discovered, so far as I can learn, no saber-tooth tigers, no horses, no tapirs, no camels, none of the many sloth-like animals that once existed, except the megalonyx. These deposits, which overlie the

[3] ARNOLD, R. and ELDRIDGE, G. H.: *The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, California.* U. S. Geol. Surv. Bull. 309: 186–195. 1907.

last drift sheet, and the fossil vertebrates found in them belong to the close of the Later Pleistocene.

Of the genera missing from the late Wisconsin fauna, the ground-sloths, the horses, the tapirs, various bisons, and saber-tooth tigers, some had survived the Kansan glacial stage. The species of the genera thus surviving are usually relatively few and the stages during which they became extinct, usually uncertain. *Mylodon*, *Bison antiquus*, and *B. latifrons*, and the tapirs dropped out probably during the Sangamon or soon after; the few horses apparently perished before or during the Wisconsin glacial stage. It seems, therefore, inexpedient to divide the post-Kansan vertebrates into two or more faunas.

PALEONTOLOGY.—*The genera* Pseudotextularia *and* Guembelina.

JOSEPH A. CUSHMAN, Sharon, Massachuetts.

The genera *Pseudotextularia* and *Guembelina* described from Europe also occur in the Upper Cretaceous of Mexico, and as the two are confused in Egger's work on the Foraminifera of the Cretaceous published in 1899[1] a few notes may help other workers on the foraminifera.

Pseudotextularia Rzehak, 1886

This genus was erected by Rzehak in 1886.[2] Later, in 1895,[3] Rzehak figured and described *Pseudotextularia varians*. This species seems to be identical with that later published by Egger as *Guembelina fruticosa*,[4] and it occurs in the Mendez member of the Upper Cretaceous of Mexico. As will be noted, other species connect the two faunas of Central Europe and Mexico. As shown by Rzehak in 1895 (pl. 7, figures 2 and 3) the early stages of *Pseudotextularia* are truly textularian, an alternating series of chambers on either side of an elongate axis, the apertures on the inner margin of newly added chambers. In the adult there occur isolated chambers near the periphery, subglobular in form, finally resulting in a spiral series about the margin, leaving a depressed area in the center. Well preserved Mexican specimens show this same series of characters. There are specimens, however, which do not attain this full generic character, and as figured by Rzehak (1895, plate 7, figure 1) still hold the textularian form. The ornamentation and general appearance are very similar in the two forms, however.

[1] EGGER. *Foraminiferen aus den Kreidemergeln der Oberbayerischen Alpen*. Abh. kon. bay. Akad Wiss. München, Cl. II, vol. 21, 1899.

[2] RZEHAK. Verh. Nat. Ver. Brünn, Sitz, 24: 8. 1886.

[3] RZEHAK. Ann. k. k. Nathist. Hofmuseums 10²: 217, *pl. 7, figs. 1–3*. 1895.

[4] EGGER, loc. cit., *pl. 14, figs. 8, 9*.

The Mexican specimens from the Mendez formation, which is the upper part of the so-called Papagallos of the Upper Cretaceous of Mexico, seem to be identical with *Pseudotextularia varians* Rzehak. Turning to Egger's 1899 work, it will be found that plate 14 has a very similar form which seems identical, figures 8 and 9, which are described as a new species, *Guembelina fruticosa* Egger. From a study of Mexican material this seems to be a synonym of *Pseudotextularia varians* Rzehak, and does not belong in the genus *Guembelina* erected by Egger.

Also in the Mendez is another species, much flattened and developing the multiple chambers very early, and finally in great numbers. This, without an opportunity of seeing the European types, would seem at least very close to, if not identical with, Egger's plate 14, figures 17, 18, 20, 21, described by him as *Guembelina acervulinoides* Egger. This should be known as **Pseudotextularia acervulinoides** (Egger).

Apparently *Pseudotextularia* is one of those genera which represents an end development, and did not persist into the Tertiary to any extent. The two species of the Mendez serve as do many others to correlate the Upper Cretaceous of Mexico and Central Europe.

Guembelina Egger, 1899

In 1899 Egger erected the genus *Guembelina* which included certain species already discussed. The typical species, however, have a spiral or bulimine early development followed by a textularian series of chambers. A typical species is *Guembelina decurrens* (Chapman) figured by Egger (plate 14, figures 1 to 4). This has a peculiar surface ornamentation of curved costae, those of each chamber independent of the others, and in general parallel to the periphery. Associated with *Pseudotextularia varians* in the Mendez is a species of *Guembelina* which is probably identical with *G. decurrens* (Chapman), still further showing the relationship of this Cretaceous of Mexico and that of Central Europe.

The genus *Guembelina*, like *Pseudotextularia*, does not seem to have persisted to any extent into the Tertiary, and the two make excellent markers for this part of the Upper Cretaceous over this wide geographical range.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ANTHROPOLOGICAL SOCIETY

584TH MEETING

The 584th meeting of the Anthropological Society of Washington was held October 21, 1924, in the new National Museum and was devoted to a symposium on *The anthropology of the Southeastern United States.*

Dr. J. WALTER FEWKES took as his subject the archaeology of the Gulf States. The speaker considered the aboriginal culture of the Southeastern United States one of the greatest of prehistoric North America, ranking in interest with that of the pueblo region. It had not, however, received the attention it deserved, though the epoch-making contributions of Clarence B. Moore and Frank Hamilton Cushing were of the greatest importance. In a general way the culture of our prehistoric Southeast, known, from the predominant tribe, as the Muskhogean or Creek, embraced Indians speaking several cognate languages. The same culture extended from Florida through Georgia, Alabama, Mississippi, Louisiana, and indefinitely toward the West. The area in which it developed was bounded on the east by the Atlantic Ocean and on the south by the Gulf of Mexico.

Attention was called to the excavation of two large mounds by Gerard Fowke, under the direction of the Bureau of American Ethnology, along the great bend of the Tennessee River at Mussel Shoals, both of which will be submerged when the Wilson Dam is closed. These two mounds are situated on Town Creek, not far from Courtland, Alabama. One, formed of mussel shells, is technically a kitchen midden, or eating place. It evidently was the locality where shellfish were brought ashore, cooked, and their soft portion eaten, the mound being formed of rejected shells. The other, or adjacent, mound contained many skeletons and mortuary objects, the most unusual of which were three copper gorgets lying on the breasts of the dead. One of these is the largest and best preserved of the objects yet collected.

During the past winter (1924), Dr. Fewkes superintended the excavation of about one-third of a large burial mound on Weedon Island, near St. Petersburg, on the west coast of Florida. He described the pottery found in it, and pointed out that in this mound there were evidences of two distinct layers, or strata: the upper contained beautiful specimens of pottery and other objects quite similar to those found along the west coast of Florida at Tarpon Springs, as far north as central Georgia; the lower layer had crude pottery and many implements made of shells. The speaker supposed that the artifacts of the lower stratum indicated that the most ancient inhabitants of Florida were related to the archaic inhabitants of Cuba, and that the upper stratum was later in time, and allied to that of the Creeks of the Southern States.

Dr. ALEŠ HRDLIČKA, took up the physical anthropology of the region. What might conveniently be called the Gulf stock of Indians is a large and highly interesting group of people who occupied at and before the time of the discovery of America large parts of what are now the states of Arkansas, Louisiana, Mississippi, Tennessee, Alabama, Georgia, and probably also South Carolina. This stock has no affinities towards the northeast or north, and must have been derived from somewhere in the northwest, west, or southwest. Present indications seem to favor eastern Mexico. Since discovery, the type, though robust and strong in numbers, has become very largely extinct except for the mixed survivors of the Choctaw. Tribes that may be offshoots of this body, though now speaking northern languages, are a part of the Osage, and the Winnebago. The more oblong-headed elements of Florida may be safely identified with the Seminoles and other Muskhogean tribes of northern derivation.[1]

[1] For details see A. HRDLIČKA. *Anthropology of Florida*, Publ. Florida St. Hist. Soc., Deland, Fla., 1922.

Dr. John R. Swanton, the third speaker, considered the linguistic and cultural relations of the Indians living in the Gulf area within historic times. He stated that the Muskhogean linguistic stock was the largest in the region, that Natchez, once thought to be distinct, is now known to have been a widely divergent dialect, and that there is good reason to suppose that some tongues spoken to the westward, as well as the Timucua languages of Florida, would prove to belong to the same group. The south Florida languages were probably typical Muskhogean, but not enough of them is known to establish the fact. Comparing the Muskhogean languages with those of the other great stocks of eastern North America, we find them associated much more closely in structure with Uchean and Siouan than with Iroquoian, Caddoan, or Algonquian. In conclusion, Dr. Swanton called attention to cultural differences between the Gulf tribes, even those belonging to the same stock, using Creek and Choctaw by way of illustration.

JOHN M. COOPER, *Secretary*

THE ENTOMOLOGICAL SOCIETY

369TH MEETING

The 369th meeting was held at the National Museum November 6, 1924, with President BÖVING presiding and 38 persons present.

Program: G. A. DEAN: *The corn borer situation.* (Illustrated.) The European corn borer, which has become firmly established in the United States and Canada, probably gained entrance into America in 1909 or 1910 in broom corn imported from Hungary and Italy, although not until the summer of 1917 was it first reported and identified in the United States. At this time an infestation, covering an area of nearly 100 square miles, was found in the vicinity of Boston.

In January, 1919, the insect was discovered in the vicinity of Schenectady, N. Y., and in September, 1919, separate infestations were found south of Buffalo and at Girard, Pa. In August, 1920, Canadian entomologists reported an infestation in Ontario, beginning near St. Thomas and extending east along the lake shore to the Niagara River. In 1921 a slight infestation was found throughout a narrow strip of territory bordering on Lake Erie in Pennsylvania, Ohio, and Michigan.

While the results of the infestations in sweet corn and garden truck in Massachusetts and the injury to flint corn in Ontario were such as to demonstrate its importance as a serious pest, there still remained in the mind of some investigators doubt as to the seriousness of the borer in large dent corn, which is grown throughout the greater part of the corn belt. However, after making an inspection tour in company with several Canadian entomologists and agricultural agents of the dent corn areas of Kent and Essex counties, and observing the serious injury caused by the corn borer to the crop of 1924, the speaker was impressed by the tremendous potentiality of this insect once it became established throughout the corn belt. Apparently the dry climate conditions during July and August that are conducive for maximum yields of corn are identical with those favorable for a rapid increase of the borers, and it would seem, thus, that the most serious loss might be expected on the best corn crops.

The life history of the insect in eastern New York, New England, and the Lake Erie region was given in detail by the speaker.

The nearly completed annual survey activities have disclosed such alarm-

ing facts as a spread of from 1900 square miles to 3350 square miles, or nearly 150 per cent in Ohio, with an average increase of 100 per cent in intensity; in Michigan a spread of from 800 square miles to 2350 square miles, or nearly 300 per cent of the original territory, with a considerable increase in intensity; and a spread of from 750 square miles to 1300 square miles, or nearly 150 per cent, in northwestern Pennsylvania, with a marked increase in intensity. In addition to these developments, a limited infestation has appeared on the northeastern side of Staten Island. One new spot of infestation has appeared on Long Island close to the commercial sweet corn center, and a series of infestations has developed along the south shore of Connecticut in the towns of Bridgeport, West Haven, Old Lyme, New London, and Stonington.

The Canadian situation, which last year seemed to be fairly well in hand, has broken out with renewed intensity, and the principal dent corn growing areas in Essex and Kent Counties, Ontario, are now so seriously infested as to cause considerable commercial injury. The prevalence of moisture, heavy dews, and high humidity during the incubation of the eggs and during the early or first instar stage of the larvae apparently caused very little mortality of the eggs, and permitted large numbers of the larvae to become established in the tassels, leaves, stalks, and ears of the corn plants.

In Massachusetts there has been not only a very marked decrease in the intensity of infestation, but also very little spread in infestation. This decrease apparently is due principally to the adverse climatic conditions which prevailed during the summer of 1923. The thorough clean-up of fields, gardens, and small weed areas and the fall plowing of practically 90 per cent of the cultivated fields probably contributed considerably to the decrease in the infestation. In eastern New York the infestation remains about the same, that is, there has been very little spread and very little decrease in the intensity of the infestation. (*Author's abstract.*)

The paper was discussed by Messrs. ALDRICH, BAKER, GRAF, ROHWER, and SASSCER.

Notes and discussion: Dr. HOWARD gave an informal talk on *Some entomologists at last summer's Stanford meeting and at the Hawaiian Conference.*

Dr. J. M. Aldrich read a note by R. C. SHANNON, entitled *Brief history of egg-laying habits of Dermatobia.* The so-called human bot-fly, *Dermatobia hominis* L. f., of Tropical America is of great interest because its larva frequently parasitizes man, but it affords considerable added interest because of its most unusual method of disposing its eggs.

Its mode of attack was long a mystery. Published accounts of the larva and its parasitism in Man date as far back as 1749, but not until 1900—150 years later—was there any definite clue as to its secret method of attack. It was, naturally, believed that the adult fly came directly to the host and laid its eggs on the skin but no authentic records were ever published to show this to be true. The natives of the region believed that the bot was acquired through the attack of other insects, and among natives of certain regions it was called mosquito-worm.

During the years 1900–1910 a number of mosquitoes were collected in various parts of Central and South America which had the eggs of another insect attached to them and these, upon dissection, showed that they contained the larva of a bot-fly. The eggs, usually eight to ten to a mosquito, were placed on the lower surface of the abdomen and pointed obliquely downward and backward in such a manner that when the mosquito is sucking blood, the free, or hatching, end is nearest the skin of the host. The eggs are arranged in compact clusters and attached by means of a strong cement-

like substance. In practically all cases the mosquitoes were *Janthinosoma lutzii*, one of the most bloodthirsty mosquitoes in the tropics, and from this it was considered that the *Dermatobia* chose only the bloodsucking mosquitoes to be the carriers for its eggs.

The more recent observations of Adolpho Lutz of Brazil (1918) give a fairly complete life history. The flies, which parasitize numerous warm-blooded animals, birds, dogs, pigs, cattle, monkeys, and man, have been noted by Lutz to be attracted to cattle and to capture the blood and sweat sucking flies on the cattle, cage them within their legs, and oviposit their eggs on them, usually on the abdomen. Flies with such egg clusters have been kept by Lutz until the larvae within the eggs were ready to hatch, and at this time, when the eggs would be placed near the skin of man or dog, the larva would hatch and after a time would burrow in the skin of the host.

As far as is definitely known *Dermatobia* confines its choice of egg carriers to blood and sweat-feeding flies which it finds about animals at the time of oviposition.

However, the writer procured a mosquito, *Goeldia longipes*, while in Panama, which as far as known is non-bloodsucking, but which bears a cluster of eggs. This may possibly indicate a new phase, either in the life history of the mosquito or in the bot-fly. If the bot-fly only lays its eggs on incects found about animals it would indicate that *Goeldia longipes* is a bloodsucker. If this species of mosquito does not suck blood and is not attracted to animals it would tend to show that *Dermatobia* will lay eggs on mosquitoes and probably on any insect, no matter where it may be.

However, the principal question is: why does *Dermatobia* come to the animals to lay its eggs on other insects when it can apparently even more effectively apply them directly to the host itself?

CHAS. T. GREENE, *Secretary*.

SCIENTIFIC NOTES AND NEWS

Titles of papers in the symposium on *Chemistry in the field of microbiology*, to be given by the Division of Chemistry of Medicinal Products of the American Chemical Society at the Baltimore meeting of the American Chemical Society, April 7–10, are: T. B. JOHNSON, Yale University: *Application of the methods of organic chemistry to the study of the structure and composition of bacteria*. CARL VOEGTLIN, Hygienic Laboratory, Washington: *Chemical aspect of the therapeutic action of arsenicals*. JOHN W. CHURCHMAN, Cornell University Medical College: *Practical and technical consideration of the local and intravenous use of dyes* (tentative title). VEADER LEONARD, School of Hygiene and Public Health, Johns Hopkins University: *Internal antisepsis in its relation to chemistry and biology* (tentative title). G. W. RAIZISS, Philadelphia: *Bacterial chemotherapy with special reference to mercury dyestuffs*. E. C. WHITE, Hynson, Westcott, & Dunning, Baltimore: *Dyes used as tests of liver function* (scheduled for the joint meeting of the Organic Division on Tuesday).